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Life cycle assessment of urban wastewater systems: Quantifying the relative contribution of sewer systems

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ABSTRACT

This study aims to propose a holistic, life cycle assessment (LCA) of urban wastewater systems (UWS) based on a comprehensive inventory including detailed construction and operation of sewer systems and wastewater treatment plants (WWTPs). For the first time, the inventory of sewers infrastructure construction includes piping materials and aggregates, manholes, connections, civil works and road rehabilitation. The operation stage comprises energy consumption in pumping stations together with air emissions of methane and hydrogen sulphide, and water emissions from sewer leaks. Using a real case study, this LCA aims to quantify the contributions of sewer systems to the total environmental impacts of the UWS. The results show that the construction of sewer infrastructures has an environmental impact (on half of the 18 studied impact categories) larger than both the construction and operation of the WWTP. This study highlights the importance of including the construction and operation of sewer systems in the environmental assessment of centralised versus decentralised options for UWS.

1. Introduction

Life cycle assessment (LCA, standardised ISO-14044) has become one of the reference methods used to assess the environmental performance of processes over their complete life cycle from raw material extraction, infrastructure construction and operation to final dismantling. Several LCA studies have been conducted since the 1990s to assess the environmental impacts caused by wastewater treatment systems as reviewed in Corominas et al. (2013). Table 1 complements the review of Corominas et al. (2013) and lists the

Abbreviations: BOD_5, 5-day biochemical oxygen demand; CH_4, methane; COD, chemical oxygen demand; CP, basic components; DIN, dissolved inorganic nitrogen; FU, functional unit; GHG, greenhouse gas emission; H_2S, hydrogen sulphide; H_2SO_4, sulphuric acid; HRT, hydraulic retention time; LCA, life cycle assessment; LCI, life cycle inventory; LCIA, life-cycle impact assessment; N, Nitrogen; N_2O, nitrous oxide; PE, population-equivalent; SE, sub-assemblies; SR, sewer subsets; UWS, urban wastewater system; WWTP, wastewater treatment plants.

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Table 1 – Literature review of sewer inventory models used in LCA studies of urban wastewater systems.

Authors	Comments	Construction						Operation		Maintenance
		Building materials and equipments	Works					Direct	Indirect	
		Stages included in the LCA inventory of sewer systems								
		Pipes (cement, PVC, metals)	Various manholes & connection systems	Pumping stations (infrastructure)	Concrete & aggregates for pipes bedding and other uses	Civil works to build the sewer on site (excavation, backfill, compaction)	Road rehabilitation on due to excavation (including bitumen)	Sewer-generated emissions of gas (CH_4, H_2S) and nitrogen leaks	Pumping stations (Electricity)	Sewer maintenance expenditures (renewal, replacement & repair interventions on pipelines, etc.)
Carbon or energy footprint approaches (i.e. inventory limited to greenhouse gas emissions and/or cumulative or gross energy demand)										
(Borghi and Gaggero, 2008)		X	1		X					
(De Sousa et al., 2012)		X	X	X						
(Herz and Lipkow, 2002)		X	1		X	X				
(Mouri and Oki, 2010)		X		X		1			X	
(Venkatesh et al., 2009)		X	X			2				
Multicriteria LCAs (i.e. inventory of all resource consumption and pollutant emissions)										
(Barjoveanu et al., 2014)		X	X						X	X (Diesel consumption, piping materials and waste produced)
(Benetto et al., 2009)	(a)									
(Doka, 2009) – Ecoinvent database v2.0	(b)	X	X		X	X				
(El Sayed et al., 2010)	(c)									
(Friedrich et al., 2009)		X	X	X					X	
(Gagnon et al., 2008)		X		X	X				X	
(Godskesen et al., 2013)		3	1	X	1	1			X	
(Lassaux et al., 2007)		X			1	1				
(Lemos et al., 2013)		6								
(Lundie et al., 2004)	(d)	X	X	X	1				X	X additional materials estimated to cope with system upgrades and maintenance included
(Remy et al., 2006)		X	X		4	5				
(Tarantini et al., 2001)	(e)									